Radiance Modeling of the HIRDLS Optical Obstruction for Accurate Trace Gas Retrievals

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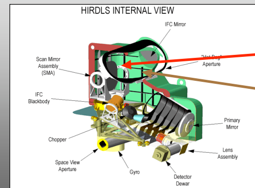
Abstract

A HIRDLS radiance profile measurement consists of an atmospheric signal together with a thermal contribution from the obstruction in the optical path. In order to obtain proper trace gas retrievals, it is critical that the obstruction's thermal signal be described to very high accuracy and subtracted off. We discuss the modeling approach currently used to both characterize and predict the obstruction's thermal state. The model provides a useful and mathematically robust description of the obstruction's signal in both space and time. This approach also provides a practical and effective framework for ongoing improvements to the HIRDLS atmospheric radiance measurements and constituent retrievals.

The HIRDLS optical assembly is partially blocked by insulating material which separated from the instrument's walls during Aura launch.

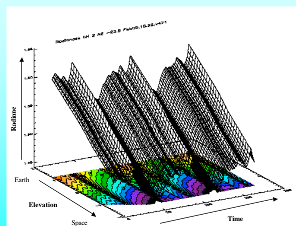


Extensive tests and modeling indicate that insulation lies in front of the scan mirror assembly, obscuring a significant portion of the atmospheric limb radiance viewed through the aperture.

What is Needed:
An Accurate Description of the Thermal Radiance from the Obstruction, Which Can be Used Operationally to Extract the Atmospheric Limb Emission From the Signal Measured by HIRDLS

Atmospheric Limb Emission = (Measured Radiance - Thermal Radiance from Obstruction) / (Open Area Fraction)

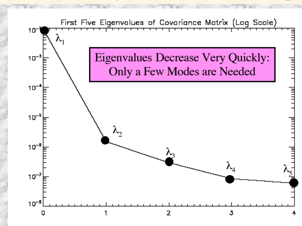
AURA "PitchUp" Points HIRDLS Towards Space, Allowing Obstruction Radiance to be Mapped in Isolation.
The Thermal Signal is Relatively Stable and Repeatable.



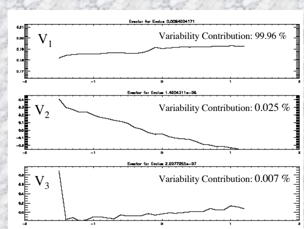
Channel 2 obstruction radiance time series shown as a surface plot, and as a color contour plot.
Data shown for scan mirror azimuth -23.5 degrees.

For operational use, the EOF analysis must be combined with a fast and accurate algorithm that will estimate the obstruction's contribution to a given HIRDLS limb radiance measurement. Required accuracy for the obstruction estimate is ~10^{-4} W/(M^2 Sr).

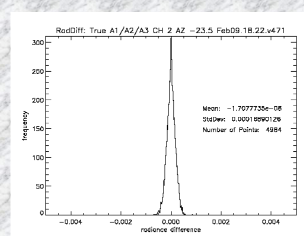
Variability in the Obstruction Radiance is Accurately Captured Through a Low-Order Empirical Orthogonal Function Analysis



Leading Eigenvectors Describe Independent Modes of Variability



Accuracy of Obstruction Radiance Reconstruction for Three-Term EOF expansion.
Standard deviation of residual error is 0.000169

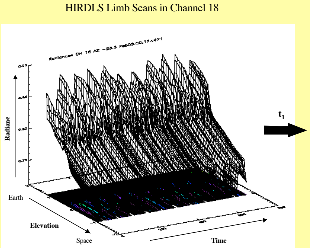


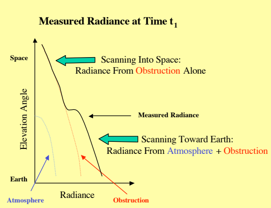
An Effective Strategic Framework for Modeling the Obstruction Radiance:

EOF modeling of the obstruction radiance during Pitchup is used to estimate the *time-dependent contribution of the obstruction radiance to each HIRDLS science scan.*
The top of each science scan measures the obstruction radiance alone. This is used to determine fitting coefficients for the pre-computed eigenvectors. Coefficients and eigenvectors are combined with a time-mean obstruction radiance to give the radiance correction. This framework is the basis for ongoing radiance modeling improvements.

1) The Upper Part of Each Limb Scan Measures the Obstruction Radiance Alone

HIRDLS Limb Scans in Channel 18

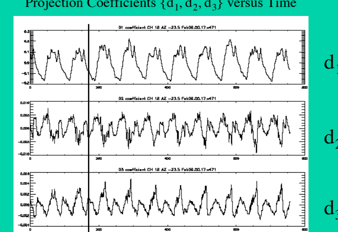


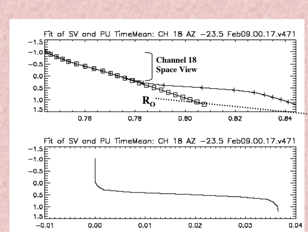


Projection Coefficients $\{d_1, d_2, d_3\}$ versus Time

2) Space-view portion of each science scan views obstruction. Determine "projection" $\{d_1, d_2, d_3\}$ of *space-view* radiance onto *space-view* portion of eigenvectors. Projections together with eigenvectors model obstruction radiance variability at **ALL** elevation angles.

Time series of $\{d_1, d_2, d_3\}$ exhibit deterministic structure tied to the orbital and seasonal cycle. The thermal behavior of the obstruction is **stable** and **repeatable**.



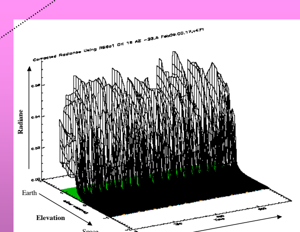


3) Estimate *time-mean obstruction radiance* by matching space-view portion of current science scan to time-mean pitchup radiance

(Upper Figure) The time-mean pitchup radiance profile has been translated and rotated (squares) to match the time-mean measured radiance (crosses). The match is done over the Channel 18 space-view elevation range [-1.0, + 0.3]. The translated/rotated profile (squares) is the time-mean estimate R_O for the current measurement.
(Lower Figure) Matching Accuracy.

4) Compute Obstruction Radiance $R_O(t_1)$ for Current Measurement:
$R_O(t_1) = R_O + \Sigma\, d_i(t_1) * V_i$

Subtract $R_O(t_1)$ from measured radiance to give corrected radiance.



Channel 18 Corrected Radiances